Original Articles.

ASPHALT PAVEMENTS; THEIR NATURE AND DESIRABILITY.[1]

BY CLIFFORD RICHARDSON, ESQ.,
Expert on Asphalt, New York.

I HAVE been asked by your governing board to present to you this evening some facts in regard to asphalt and asphalt pavements, from the point of view of the engineer, and to explain the advantages which are offered by such pavements for abating the dust nuisance, the matter which you have especially under consideration.

It may interest you, to begin with, to learn something of the origin and extent of the industry.

ORIGIN AND HISTORY OF THE PAVING INDUSTRY.

Although the application of asphalt to industrial purposes on a small scale dates back to the earliest times, it is only with the introduction of rock asphalt into Paris about forty-five years ago that the asphalt paving industry can be said to have originated.

In 1838 the first sidewalks were laid in Paris with bituminous limestone from Seyssel and Val de Travers. In 1849 Mercau, a Swiss engineer, noticed that at the quarries pieces of the rock which fell from the carts united under the influence of heat and traffic so as to form a concrete mass, and on this principle he constructed a road in the village of Travers upon a macadam base. M. Darcey, inspector-general of bridges and roads in Paris in 1850, made a report recommending the use of compressed asphalt, and after some experiments a pavement of this material was laid in the Rue Bergere in 1854. In 1858 another trial was made on a larger scale in the Rue St. Honore, and from that time on the Parisian asphalt pavements were laid. In London, the first asphalt pavement was laid in Threadneedle Street in 1869. In Paris there are about 450,000 yards of asphalt pavement and in London about 400,000. But the amount has not increased of late years owing to the slipperiness of this form of asphalt surface. In Berlin the first asphalt pavements were laid about 1873 or 1874, and since then very large amounts have been put down, reaching about 1,700,000 square yards. Pavements of this description have never been popular, however, in America.

The success of asphalt pavements in Europe led to much experimenting in this country, and at first coal tar was used as a cementing material. Between 1870 and 1873 a large area of such pavements was laid in Washington, a majority of which proved worthless, and grave suspicion was thrown upon coal tar as a cementing material.

In 1870, De Smedt began experimenting with Trinidad asphalt with a view to overcoming the defects of coal tar, and laid a sample pavement in Newark. He took out a patent for his invention. In 1871 or 1872 he laid an asphalt pavement around Battery Park, New York, and in 1873 one on Fifth Avenue in front of the Worth monument, which remained in use, with one or two resurfacings, until 1886. At about the same time Trinidad asphalt was laid in Philadelphia, on Sixth Street, in front of Independence Hall. In 1874 or 1875 Eighteenth Street was paved with Trinidad asphalt between Fourth Avenue and Irving Place, as were several other New York streets. The pavements were successful and attracted much attention. In 1876 Congress passed an act providing for the paving of Pennsylvania Avenue in Washington, under a commission composed of Gen. H. G. Wright, Gen. Q. A. Gilmore and Architect Edward Clark, of the Capitol, with no restrictions as to price or kind of pavement. The two former gentlemen, of the Corps of Engineers, U. S. Army, had been stationed in New York and had noted the success of the asphalt surfaces. The board therefore decided to lay compressed asphalt, and divided the work into two parts, using rock asphalt from the Capitol to Sixth Street, and Trinidad for the remainder. The rock was imported from the Val de Travers mines, and the work done by the New York Neufchatel Asphalt Company, of which Matthew Taylor was president. The contractor for the Trinidad surface was the New York and Grahamite Asphalt Company, with which De Smedt was connected. The rock asphalt pavement was condemned as being "too slippery for practical use," and no more of it has been laid in Washington.

The Trinidad asphalt was a success, and was so satisfactory that when the permanent board of commissioners was organized in 1878, they decided to limit the pavement of streets to Trinidad asphalt except where grade or traffic were prohibitory. Since that time the asphalt paving industry has rapidly expanded. In 1882 pavements of this description were laid in Buffalo, N. Y., which are still in fair condition. In that year asphalt was introduced in Omaha, Neb., and Youngstown, O. In 1883 the business extended to Baltimore, Philadelphia, Boston, Erie, St. Louis and Louisville, and from that time on has spread to 105 different cities in the United States, in which over 31,000,000 yards of asphalt concrete pavements have been laid by the several companies which have been engaged in the business. This extent of surface would amount to 1,950 miles of streets 26 feet wide. Of all this surface 26,000,000 square yards have been laid with Trinidad asphalt, the remainder with other asphalts, including about 1,000,000 yards of bituminous limestone rock from the Continent.

On the entire Continent of Europe there are only 4,000,000 square yards, or 250 miles of streets, all of which is constructed with bituminous limestone.

On the first of January, 1899 (the figures for January, 1900, are not yet available), some of the prominent cities of the United States had the following areas of asphalt pavements: Buffalo had about 3,900,000 square yards; Washington, about 2,600,000 square yards; New York, about 1,600,000 square yards; Boston, only 195,000 square yards.

In the smaller cities of the West asphalt pavements are extremely popular, and I may cite the town of Shelby in Ohio, which, with a population of only 6,000, put down in 1899 30,000 square yards of asphalt, or about 5 yards to every inhabitant. If Boston were paved on this scale it would have nearly 3,000,000 yards, or about the same as Buffalo. Every year asphalt pavements are introduced into numerous towns and cities, and the popularity of this form of roadway is growing rapidly.

In this connection it may be of interest for you to know what asphalt is, how it is obtained, something of the technology of the industry, the forms of construction, the extent of these pavements here and

[1] Read at a meeting of the Boston Society for Medical Improvement, February 19, 1900.

abroad, and their success and popularity as shown by the increasing demand for them.

WHAT IS ASPHALT?

Asphalt exists in nature and is not a by-product of manufacturing processes, like coal tar, as is often erroneously believed. It is a mineral found widely scattered over the earth's surface, but only rarely in commercially available quantities. It is also known as mineral pitch.

Asphalt, or more properly asphaltum, the essential constituent of asphalt, is a form of native bitumen. Bitumen is a mixture of hydrocarbons, with their derivatives which contain sulphur, nitrogen and more rarely oxygen, and may be either gaseous, liquid, viscous or solid, softening or melting when solid on the application of heat, and soluble in chloroform and similar solvents. Asphaltum is that variety of bitumen which is solid, or nearly so, at ordinary temperatures, melts rapidly on the application of heat, and contains a very considerable amount of sulphur derivatives. Maltha, or mineral tar, is a similar bitumen existing as a very viscous liquid and containing less sulphur. It grades from heavy petroleum to the less solid asphalts and is often called soft asphalt.

Asphalt is a name commonly applied to any mineral matter containing a considerable quantity of asphaltum, this form of bitumen being oftener found combined with limestone, sand, clay, soil, and, as in Trinidad asphalt, with sand and clay rather than in a pure condition, where it is characterized as glance pitch, the name applied to the bitumen of Judea or the asphalt of the Dead Sea. Asphalt is a secondary, or transformation, product of petroleum, being the result of the changes to which this lighter form of bitumen has been subjected under certain environment and especially in the case of petroleums containing hydrocarbons of a particular composition.

SOURCES OF ASPHALT FOR PAVEMENTS.

On the Continent of Europe there are large deposits of limestone impregnated with from 6% to 11% of bitumen which are mined to quite an extent for paving purposes. This material cuts no figure in the industry in this country.

The chief sources of the supply here are the pitch lake of the Island of Trinidad, that in the State of Bermudez, in Venezuela, and smaller amounts from California.

DESCRIPTION OF ASPHALT DEPOSITS.

The Trinidad deposit. — The Island of Trinidad is the largest colony of Great Britain in the Antilles, with the exception of Jamaica. It lies but a short distance from the mainland of South America, of which it was plainly once a part, near the most northerly and westerly of the mouths of the Orinoco and the coast of Venezuela, being separated from the latter by the Gulf of Paria. On the Gulf Coast and at an altitude of 138 feet above the ocean and 1,100 yards from the shore is the celebrated pitch lake described by so many writers, including Kingsley in "At Last." The lake is a level expanse of 114 acres of black pitch, over which one can walk or ride in any direction except where interrupted by shallow water courses between the several areas of asphalt. The latter appear like the tops of a mass of mushrooms which have been gathered together at their edges. They are prevented from remaining together or coalescing by the water between them. At the centre fresh pitch is continually being emitted in a very soft condition but at a temperature not above that of the air and there the weight of a man can also not be sustained.

The surface is bare except for a slight growth of grass near the edges and a few masses of larger bushes, small trees and grass floating on the inner part of the lake, whose movements can be detected from year to year. In fact, from an evolution of gas which is taking place in the pitch, the entire material of which the deposit is composed is in a constant state of motion. Stakes driven in the pitch in a straight line are after some days quite out of alignment, and substances left upon the surface are engulfed, perhaps to appear years afterwards. The pitch, although in a constant state of motion, is sufficiently brittle to admit of its being flaked out, like ice, in masses of 50 pounds or more and an excavation thus made will close up and disappear in a few days. Borings in the centre of the lake made in 1894 penetrated the deposit to a depth of 135 feet and were still in pitch. With the extensive area of the lake and this depth, the quantity of asphalt in this deposit must be enormous, in the millions of tons, while at the same time levels taken of the surface of the lake in connection with the accurately recorded amount of material taken from it since the material had been sought, more than 1,200,000 tons, shows that the surface has not fallen as much as it should have done were there no present supply of fresh asphalt, and it appears that from 18,000 to 20,000 tons run into the lake every year, in itself no small supply.

The crude asphalt of the lake is a peculiar substance. It is a mixture, or emulsion, of asphaltum, gas, water, mineral and organic matter not bitumen in the following proportions: Water and gas, 29%; bitumen, 39%; organic not bitumen, 7%; mineral matter, 25%; total, 100%. And it is still more remarkable that the composition of the pitch is so uniform that no matter on what part of the surface or at what depth it is taken it is always the same, ranging less than 1% in any constituent. This uniformity in quality is, of course, of great value in any industrial process.

On the Trinidad lake there is a cable railway in the form of a loop on which cars carrying buckets run and are filled with pitch. The buckets on reaching the edge of the lake are hoisted to an overhead conveyer, upon which they are carried to the sea and out upon a pier where they are dumped directly into the hold of the vessel lying alongside, as much as 750 tons being handled in a day. The flakes of crude asphalt settle together in the hold of the vessel and at the end of their voyage have become a solid mass which must be again picked into flakes to discharge cargo.

The Bermudez deposit. — On the opposite side of the Gulf of Paria from Trinidad and about 30 miles in an air line from the coast the asphalt deposit, known as the Bermudez Pitch Lake, is found at the point where a northern range of foothills comes down to the swamps. The Guanaco River, a branch of the San Juan, one of the large estuaries of this region, at about 65 miles, in its winding course, from its mouth, runs within 3 miles of the deposit, but it is 5 or 6 miles to a suitable wharfage site. The so-called lake is situated between the edge of the swamp and the

foothills in what might be termed a savanna. It is an irregular shaped surface with a width of about a mile and a half from north to south and about a mile east and west. Its area is a little more than 900 acres, and it is covered with vegetation, high, rank grass and shrubs, 1 to 8 feet high, with groves of large moriche palms, called morichales. One sees no dark expanse of pitch on approaching it, as at Trinidad pitch lake, and except at certain points where soft pitch is welling up, nothing of the kind can be found. In fact the deposit is nothing more than the exudation of a vast quantity of maltha from various springs which has spread over the swamp around and become hardened by exposure and the burning of the vegetation of the swamp.

At different points there is at most a depth of 7 feet of pitch, while the deepest part of the soft maltha is only 9 feet and the average of the pitch below the soil and coke only 4 feet. At points there is not more than 2 feet of pitch and in the morichale, or palm groves, it is often 5 feet below the surface. It is plainly quite a different deposit from the Trinidad lake, and on further examination the material is found to differ essentially from the Trinidad pitch. Analyses show it is far from uniform in composition. The asphalt, or matter as evolved, contains no water or mineral matter. Considerable amounts of these substances soon become mixed with the pure bitumen mechanically after it has appeared at the surface, so that the average composition of the original material and that which has become altered is as follows:

	Original Soft Asphalt.	Hardened Highest.	Asphalt Lowest.
Water or loss 212° F.			
Dried Material.	1.0	46.2	10.7
Mineral Matter	.0	3.7	.5
Organic not bitumen	.2	6.5	.6
Bitumen	99.8	98.5	90.1

The bitumen, too, in Bermudez asphalt softens and melts at a much lower temperature than Trinidad asphalt. This asphalt is shipped like that from Trinidad and refined in the United States. It makes a good pavement, but requires greater skill to handle it successfully, as it is so far from regular in composition.

CALIFORNIA ASPHALT.

There are vast quantities of bitumen scattered over a wide area in California, especially in Santa Barbara, Ventura, Los Angeles and Kern Counties. This bitumen is in the form of true asphalt and of maltha or asphaltic petroleum. The hard asphalts are not in large enough deposits to be available to any great extent commercially, although they have been used in an experimental way. The asphaltic petroleum and maltha are valuable materials when properly used, but must be handled with skill to give satisfactory results.

No asphalts as we know them to-day can compare with that of Trinidad for uniformity and ease of handling. In any case, however, skill in handling the particular asphalt is of as much importance as the material. An unskilled person cannot make a good pavement of the best material.

REFINING AND TECHNOLOGY.

Asphalt for use in the form of pavements laid in the United States must be refined to remove water, light oils, volatile at a temperature below 325°, and such organic or mineral substances as are undesirable. This is done by melting and volatilization of the water and oil, and separation of the mineral and organic impurities by skimming and subsidation. Mineral matter if not present in too large an amount or in size too coarse to remain in suspension in the melted asphalt is not objectionable. Refined asphalt cannot be produced from any single deposit which will be satisfactory for immediate use in a pavement. It must be combined with other asphalts or fluxes so that the resulting mixture shall have a consistency which experience shows is suitable for the conditions to which the pavement is to be exposed. For this purpose the residuum left on distilling off the lighter oils from eastern or California petroleum is used. The material thus prepared is known as asphalt cement. This must be mixed with a suitable mineral aggregate consisting of sand and a fine filler or dust to form a bituminous concrete wearing surface for the pavement. As the mineral aggregate forms 85% to 90% of the surface it is just as important that it should be of satisfactory quality and properly selected as it is that the consistency and character of the asphalt cement should be right. In the early days of the industry this was neglected and often poor pavements were the result, but with the experience of years the best equipped companies are now in a position to avoid mistakes of this description, and it is probable that the best asphalt surfaces of to-day are far in advance of those of 1880 in their ability to withstand traffic and other conditions which tend to cause a disintegration of the surface. The gritty mineral aggregate and the asphalt cement are mixed at temperatures in the neighborhood of 300° F., spread upon the street and compacted in a way which you probably have all seen in Boston. Skill is of course necessary in all parts of this process also, and cheap workmanship must be avoided.

Attempts have been made again and again to construct pavements with artificial bituminous materials, such as by-products of manufacturing processes, coal tar, petroleum sludge, etc., as a cementing material, but always with more or less disastrous results. Nothing but native bitumen free from decomposition products of manufacturing processes can be satisfactorily used for this purpose.

FORMS OF CONSTRUCTION OF ASPHALT PAVEMENTS.

Asphalt pavements generally in use in the United States at the present day consist of three parts, a base, a binder and a wearing surface. Depending upon local conditions the nature and thickness of these courses vary.

Under pavements to be subjected to heavy traffic or upon a weak subsoil a hydraulic concrete base should be, and usually is, provided. Its thickness depends upon circumstances and may be from 4 to 6 inches. This base supports the weight of the traffic on the pavement and is a most essential feature. Upon the base a binder course consisting of clean broken stone of a size that will pass a 1-inch ring, heated and covered with a coating of bituminous cement, is placed and compacted to a depth of 1 to 1½ inches. This course prevents the surface from moving or creeping on the smooth base and is an important element in preventing its pushing out of shape, as happens so frequently with rock asphalt surfaces. Upon the binder the gritty surface is placed and compressed into its interstices until the whole is a mono-

lithic mass. The depth of the surface may range from 1 to 2 inches according to requirements. Residence streets are satisfactory with an inch of binder and the same of top. On business streets 1½ inches of binder and 2 inches of top are more suitable.

Oftentimes it is possible to use as a base some form of old pavement which has been consolidated by traffic into an unyielding mass quite as suitable to support an asphalt surface as a new hydraulic base. For this purpose old granite block, brick and macadam have been used. In New York City between 1,000,000 and 2,000,000 of old block pavements have been covered with asphalt and the old macadam surface on Broadway between Fifty-ninth Street and 118th Street has been resurfaced in the same way, some of the asphalt having been in place with slight repairs since 1890. Worn-out brick pavements have also been successfully resurfaced in Ohio. In such cases a binder course is laid upon the old pavement to bring it to grade, and upon this the surface is laid.

THE PERFECT PAVEMENT.

There is nothing which offers such good evidence of the well-being and the good government of a city as the condition of its streets. Their first appearance to a visitor is the foundation of his impression of a town, which it is difficult to dispel if unfavorable. When paved with a perfect pavement which is clean, the initial impression is favorable.

The perfect pavement has been defined as one whose cost and that of maintenance is reasonable, whose surface offers the least resistance to traction consistent with a good foothold for horses, which is impervious to moisture, offers no irregularities for retaining dust, produces no detritus itself, is easily cleaned, kept cleaned and is as noiseless as is possible.

Asphalt, I believe, approaches these conditions more nearly than any other form of pavement, and I shall endeavor to show that at the same time it possesses qualities which render it desirable in other ways, some of which are common to all smooth pavements but which are more strongly developed in asphalt than in other forms.

It is unnecessary for me to tell you that the defects of macadam pavements are that they make the most detritus of any kind of pavement, and in consequence, when dry, are dusty, when wet, muddy; that their resistance to traction is high; that the cost of maintenance is higher than that of any form of roadway; that it cannot be kept clean, but that to keep down the dust it must be watered and made muddy; that the cost of the best possible cleaning is high, and that storm water washes quantities of detritus from it into the sewers which must be removed at great expense. The only claim for its excellence is that it affords a good foothold for horses and this is very much exaggerated in comparison with asphalt. There is no doubt that for fast and careless driving macadam offers the safer footing, but when used for ordinary traffic the difference is slight.

Granite pavements are rough, very noisy, difficult to clean and do not admit of perfect repairs, although in other respects satisfactory. Brick have the same objections as granite to a smaller degree, and wood is inadmissible in our climate.

Our final recourse must therefore be, and has been, as will be shown, to asphalt, both as a necessity and a luxury. I trust you will allow me to explain the reason for this in more detail.

COST.

Asphalt is eventually the cheapest form of pavement that can be laid when it is considered that it is guaranteed to be kept in repair by the contractor for five years or more, when opened for excavations can be repaired with greatest ease and perfection and maintained for the city after the expiration of the guarantee for a long period of years at a reasonable price, can be more cheaply cleaned and causes less wear and tear upon horses and vehicles than any other form of pavement, thus benefiting the community in a very general way.

It may originally cost double the price of a macadam surface, but the repairs upon the latter are so expensive that often in three years the cost has been equalized, while the asphalt pavement may be maintained for many years at a cost of from two to ten cents per yard per annum, and finally resurfaced for half its original cost. In Buffalo asphalt pavements are in use to-day which, with a few minor repairs, have been subjected to traffic for twenty years, and the same is the case in other cities.

We have in the asphalt pavement, therefore, cheapness and durability combined, because economical maintenance, and not cheap first cost, is the best economy.

This, however, is true of asphalt pavements only if, as has been said, the highest grade of material is used and the most skilled labor employed, because nothing is more worthless or expensive to maintain than an inferior bituminous concrete. The prices paid must be large enough to warrant good work. Too cheap pavements are the most costly in the end because necessarily inferior.

The success of asphalt pavements early led, as has been said, a large number of irresponsible persons to go into the business with a resulting demoralization of prices, and many pavements or imitations of them have been laid upon which more was expended for repairs than would equal the cost of original high grade surface. Imitations of asphalt have been introduced at frequent intervals to the taxpayer, who has only learned of their inferiority by experience. Washington years ago went through this experience with coal tar and to-day there is still too much similar experimenting going on with by-products of manufacturing processes.

The chief cause of failure in asphalt surfaces is, however, lack of skill and experience on the part of irresponsible contractors.

ASPHALT PECULIARLY ADAPTED TO PERFECTION OF MAINTENANCE AND REPLACEMENT OF CUTS.

The necessity of prompt repairs is a fact that is self evident on a railway, but is not always so carefully regarded in connection with pavements. Too many pavements, whether stone, brick or macadam, are allowed to deteriorate until they are in a bad condition, because they are not actually dangerous and because satisfactory repairs are expensive and generally impossible. It is not possible to replace a stone block or brick pavement in such a way that the repairs are invisible, but with asphalt this is quite possible, and, as the latter surface shows the smallest defects, attention

is attracted to its condition at once and repairs are not so readily neglected.

Repairs to asphalt pavements for the first five years are guaranteed by the contractor for any deterioration of the material other than cuts and can be again contracted for with him for a subsequent period at a reasonable cost. Cuts made for gas, water or sewers can be replaced in an asphalt so perfectly that the place cannot be detected, and if it is necessary to renew the entire surface of a street, this can be done by softening the old surface with heaters to the depth of one-half to three-quarters of an inch, removing the inferior material and replacing it with new surface. It is quite unnecessary, as in former times with asphalt and now with other pavements like granite and brick, to tear up the old surface to the foundation. The economy in this direction is immense.

Of course the cost of maintenance of a pavement, asphalt or stone, depends upon the traffic to which it is subjected. But an asphalt pavement can be maintained under the heaviest traffic at a reasonable expense.

FOOTHOLD FOR HORSES ON ASPHALT.

The surface of an asphalt is a favorable one for horses as compared with other pavements. It is gritty from the sand used in its composition, except in the form laid with bituminous limestone on the Continent and to a small extent in your city. There is no grit in this surface and its use has been abandoned in Washington, New York and other cities where it has been tried.

An investigation of the relative number of falls of horses on the surface made with sand and asphalt as compared with other pavements was made in 1885 by Gen. (then Capt.) F. V. Greene. The results were presented to the American Society of Civil Engineers in a paper read December 16th of that year, which contains a large amount of interesting information as to different pavements. General Greene showed that in 192 days on 32 different streets of 10 cities, and including 807,552 horses travelling 81,051 miles, the average horse would travel the following miles before falling: On asphalt, 583; on granite, 413; on wood, 272; I am aware that to many persons who have only had a limited experience in driving on asphalt this seems doubtful, but the figures have been confirmed several times, and in cities like Washington and Buffalo, where all the pavements are asphalt, no such feeling would be found. It is true, however, that horses which have been accustomed to travelling on stone pavements are not at home on asphalt, but soon become so.

Again, persons are tempted to drive much faster and more carelessly on asphalt than on stone or macadam, their own personal comfort on the latter pavements controlling the speed. Falls on asphalt are generally due to careless driving. It has been claimed that asphalt surfaces are injurious to horses on account of the continual pounding on such hard surface. An investigation in Washington some years ago disproved this.

In 1892 one of the street railroads introduced a new motive power doing away with horses. In renewing their tracks asphalt was placed between the rails and in the interval between its being put down and the final discarding of horses they were driven for several months over the asphalt surface. It was held by the Society for the Prevention of Cruelty to Animals that this would injure the horses seriously and that it fell within their province to look into the matter. Every opportunity was given its agent to examine the animals before they were used upon the smooth surface, while they were travelling over cobbles and during the time they were on asphalt and afterwards. Although prejudiced against asphalt pavements, the observer was obliged to report that the horses were in better condition at the time they were removed from the road than when they were in use on stone pavements.

A personal friend of mine in Washington, a breeder of horses and careful observer, said to me in this connection: "If one drives with as much care on an asphalt surface as one would do for his own comfort on a rougher pavement, no injury would ever be done to the horses."

The very general approval of asphalt pavements by the engineers of our city fire departments is striking evidence of their desirability and the increased rapidity with which engines can reach fires greatly increases the efficiency of our firemen.

EASE OF TRACTION ON ASPHALT.

A characteristic of a perfect pavement is ease of traction. Numerous experiments have been made to compare the resistance to traction of asphalt and other forms of pavements, and show that the relative force required to draw a load upon different surfaces was

On tramway	1
" asphalt	1.55
" best granite block	3 to 4.1
" macadam, best	3
" poorest cobble	14 to 25
" ordinary road cobble	8 to 13
" sleigh, on snow	7

The economy of the cost of the transportation of the very large amount of material annually hauled over our city streets upon asphalt instead of rough surfaces is therefore enormous. Calculations based upon the above results show that, if they are right, by the introduction of asphalt pavement into a city previously paved with stone, the same amount of work could be done by one-half to one-third less vehicles at a money saving in our large cities of many millions, a large sum in comparison with the cost of the pavement. Or, looked at in another way, three times as much work could be done with the same number of teams.

THE HEAVIEST TRAFFIC IS SUSTAINED BY ASPHALT SURFACES.

Asphalt surface will sustain as heavy aggregate traffic and single loads as any form of pavement. Asphalt has been maintained on several blocks of Fifth Avenue, New York, for four years without a particle of repairs, and for three years on the entire avenue from Ninth to Fifty-ninth Streets with no repairs to the main mass of the pavement, but only along rails or around steam boxes at local points. Asphalt has been maintained on Chambers Street since 1886. This street has an aggregate traffic hardly exceeded by any business street in New York, and one so concentrated by a car track in this narrow street that it is made additionally severe. On Fifth Avenue in New York a cable weighing 42 tons on a truck weighing 9 was hauled over an asphalt surface in 1893 without damage or even marked depression, and since that time similar loads have been hauled without remark.

In addition to the capacity for resisting traffic under circumstances, asphalt surfaces are not disappointing in an emergency. In 1898 in Rockford, Ill., a gravel train of fifty cars left the rails and ran back upon the asphalt pavement of one of the streets through an open switch. The engineer reversed his locomotive and hauled them all back on the track with no damage to the train and no more to the pavement than a slight crease which soon rolled out.

There can be no question, therefore, but that asphalt surfaces when properly constructed have a capacity as great as any form of pavement.

INCREASE IN THE VALUE OF PROPERTY.

Asphalt pavements largely increase the value of property when placed upon unimproved streets or upon streets previously paved with noisy or dirty pavements. Before 1891 Seventh and Eighth Avenues in New York were very similar in their character, but in that year Eighth Avenue was paved with asphalt. To-day the contrast between the two streets is striking. Eighth Avenue is now a flourishing business street, horse cars have been replaced by underground trolleys and the traffic through it is enormous. Seventh Avenue, with its rough granite blocks, has little business or traffic, horse cars are the public conveyance, and the street is deserted for the superior conditions found in the next parallel street. Rents are, of course, correspondingly lower.

ASPHALT PAVEMENTS IN THEIR RELATION TO CLEAN STREETS.

The dirt in our streets is a mixture of various forms of mineral and organic matter. It contains: (1) The detritus of the surface; (2) the results of abrasion of vehicles and horse shoes; (3) dirt forced up through the joints of certain forms of pavements; (4) horse manure; (5) house and other refuse. In this mixture, when moist, organic growths of various kinds flourish, and when it is dried their growth is merely inhibited and they are not killed. In the latter form as dust, the street dirt is carried aloft by the winds and distributed through the finest crevices in windows and doors into our houses. An examination of the dust of our houses shows that it is the dust of our streets, and to do away with the former means removing the latter before it is blown about by the winds.

It is asked what kind of pavement makes the least dirt; that is to say, the least detritus. There is no question which makes the most; that is, macadam, and asphalt undoubtedly makes the least, since it practically makes none.

It is a common idea that on streets paved with asphalt a fine black dust derived from the pavement is found in the neighboring houses. It is an error to suppose that this dust contains asphalt, because for structural reasons the entire asphalt surface would go to pieces at once if any particles at all were detached from it, while it has been found on the contrary that after twenty years' use the thickness of asphalt surfaces is not appreciably changed from that which they had when they were laid. Of course surfaces which wear into holes will make detritus, but this should not occur in a first-class pavement, or, in the rare cases where it may happen, immediate repairs should remove the cause.

Dirt and dust will collect on asphalt pavement as it does upon our polished dining-room tables and it is of course more noticeable there than on macadam, granite block and other surfaces, where dust is compacted in the interstices between its separate parts. In consequence the cleaning cannot be neglected. It *must* be done. If asphalt is not properly swept half of its advantages are lost.

The smooth surface of this form of pavement can, however, be kept as clean as a house floor by sweeping or by flushing, and if dust is to be avoided this must be done. Too often the cleaning is neglected, and then, of course, dust has a free sway on being moved over the surface by the wind. It is not the form of pavement alone which must be considered, but the perfection of the methods employed in cleaning it and the opportunities which the latter offer for its being done satisfactorily, quickly and economically.

Statistics collected by Byrne show that the dirt collected daily from different pavements will average per 1,000 yards

Asphalt	.007 to .01 cubic yards,
Wood	.04 " .20 " "
Granite	.015 " .25 " "
Macadam	.10 " .35 (50 times asphalt),

and that the relative cost of cleaning different kinds of surfaces is: Asphalt, 100; granite 150; Belgian, 160; cobble, 400; that is to say, asphalt can be kept clean for two-thirds of the cost of granite block and at a still greater economy over other forms of pavement.

Cleaning of asphalt can be readily accomplished either by hand or machine methods. By hand the surface is kept clean at all hours of the day at a cost but slightly larger than that of machine work done but once in twenty-four hours or more. Hand cleaning as introduced by Colonel Waring in New York is undoubtedly the only satisfactory system in streets of heavy traffic, such as Fifth Avenue in New York and Beacon Street in Boston.

NOISE.

Of the effect of noise upon the nervous system it is useless for me to speak to gentlemen of your profession. With perhaps the exception of macadam there is no surface less noisy than asphalt. Wood gives out a rumble which is quite as distinct as the click of asphalt, while brick is perhaps more noisy than stone. In cities paved with stone there has been a great demand that asphalt surfaces shall be laid about hospitals and public offices.

A comparison of the Fifth Avenue in New York of to-day and that of a few years ago with its rough granite blocks will convince any one of the desirability of asphalt. In the hours of busy traffic in 1895, conversation could hardly be carried on as two persons walked up the avenue. To-day there is comparative quiet. Asphalt is the friend of every one with nerves.

As a matter of pure luxury we have to-day rubber shoes for our horses and rubber tires for the wheels of our vehicles. With these auxiliaries and asphalt pavements traffic becomes at once noiseless.

With the advent of the motor vehicles and the so-called horseless age, the demand for asphalt pavements will undoubtedly increase. The combination of the two will then of course give us a street which will be the ideal for cleanliness and freedom from noise.

REPAIRS TO VEHICLES.

In 1880 M. Darcy, then Director of Public Works in Paris, made quite an elaborate calculation of the saving which would be effected in the wear and tear of the 48,000 vehicles in Paris by changing all the rough stone into smooth-surface pavements. The result of the calculation was a saving of $1,092,000 per annum. M. Barrabant, the chief engineer of Paris in 1884, in citing these estimates, states that "if made to-day they would give without doubt figures more striking." His average saving, it will be noticed, is only $23 per vehicle, which certainly would seem to be moderate. In New York in 1888 there were 20,441 vehicles licensed for public hire; this does not include the trucks, wagons and carriages owned by individuals, firms or corporations and used for their own business or pleasure. The number of these is not of public record, but it is probably at least double the number of vehicles licensed for hire. If so, the total number of vehicles in New York is about 60,000, and the saving in wear and tear as a result of smooth pavements, according to M. Darcy's figures, would be about $1,500,000 per annum.

A similar calculation, according to the *Philadelphia North American* of October 12, 1885, showed that repairs to vehicles necessitated by their use on the old-time cobble-stone pavements of Philadelphia amounted to enough every year to pay the interest on the bonds which it would be necessary to issue for paving the city with Trinidad asphalt, the entire saving to owners being determined as over $100,000,000 annually.

I have been informed by carriage builders that in cities where all the pavements are asphalt, persons buying carriages are much more critical and demand a higher grade of workmanship, as the slightest defects are revealed on the smooth pavements which are concealed by the noise of the rougher kind.

SPRINKLING.

The sprinkling of streets to lay dust should not be tolerated. It is a makeshift, and merely covers up the lack of cleanliness, at least with asphalt pavements. With those forms of pavement having large interstices which cannot be thoroughly cleaned, sprinkling may become a necessity. The only way that water should be used on asphalt pavements is in flushing them from a hydrant, and this is the ideal way of keeping them clean. It may be done with either salt or fresh water without injury to the surface.

HYGIENIC DATA.

The best evidence of the desirability of asphalt surfaces from a hygienic point of view is offered by the death-rate in various cities as compared with the class of pavements which are in use in them and the degree of cleanliness practised. The following list of cities furnishes some interesting data:

Berlin:	Almost all asphalt pavements; death-rate per thousand inhabitants per year . .	19.6
Amsterdam:	Stone and asphalt, streets washed .	20
Rome:	Streets nicely cleaned, much asphalt, hard climate	21.2
Vienna:	Little asphalt, much stone and macadam .	24.3
Dublin:	Granite, cobble and macadam fairly cleaned	29.3
St. Petersburg:	Cobble and macadam, notwithstanding cold climate, which kills germs .	30
New York:	1892, with little asphalt	38.37
	1894, more asphalt	30
	1896, more asphalt and clean streets because easily cleaned . . .	26

In addition to the above data it is of interest to note that the death-rate from bowel complaints in New York City decreased from 11.5 in 1892 to 6 in 1896 per 1,000. This decrease is directly connected with the pavement of the tenement house district on the East Side of New York with asphalt, and also to the increased cleanliness of the streets which was possible with this form of pavement.

RELATION OF ASPHALT PAVEMENTS TO ILLUMINATING GAS.

It has been claimed that asphalt surfaces prevent the escape to the outer air of gas which has escaped from leaky mains, and that on this account the escaping gas is forced into our houses. This is quite a mistake, at least as far as the asphalt portion of the pavements is concerned. The hydrocarbons of illuminating gas are readily absorbed by asphalt and through the ordinary surface gas works its way, readily acting as a solvent and disintegrating the material. Asphalt therefore cannot in any way confine coal gas. The hydraulic base under an asphalt pavement may prevent to a certain extent the egress to the air of gas from leaky mains, but as such a base exists under all well laid pavements any such disadvantage is common to all forms of pavements and is not peculiar to asphalt surfaces. The asphalt surface, on the contrary, is the most desirable in this respect, as it reveals the leak at once by the disintegration which takes place and makes possible its correction.

In the light of these considerations it would seem that it would be profitable for Boston to abandon her macadam streets and the enormous cost of maintaining and cleaning them, without effectually doing away with the dust nuisance, and to lay asphalt pavements at an outlay which, with a sinking fund to pay for them, would eventually involve the expenditure of no more money than is at present laid out for the expense of their maintenance, for cleaning and watering them, and for excavating from the sewers the material washed into them from the macadam. The advantage to the health of the inhabitants is of course one which appeals directly to the members of your association.

THE TRANSPORTATION OF DISEASE BY DUST.[1]

BY HAROLD C. ERNST, M.D., BOSTON,
Professor of Bacteriology, Harvard Medical School.

THE possible injury from such a dust nuisance as we have had this winter may be looked at from two points of view: the irritant action upon the respiratory apparatus, and the transportation of pathogenic bacteria. Of the irritant action there can be no doubt, as is illustrated by the photomicrographs of the dust from the street and the window-sill of the laboratory. The fields shown are not picked, but are from the first that were found to be thin enough for photographic purposes. They show a variety of minute jagged particles, of mineral and vegetable origin, that it is manifest would be injurious in their irritant action upon inhalation and lodgment upon any weakened spot.

That this material also carries living forms is illustrated by the slides, so far as the higher bacteria are concerned, and by the cultures that Dr. Coolidge has been good enough to make for me. In these the

[1] Read at a meeting of the Boston Society for Medical Improvement, February 19, 1900.